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Inflight Deployment, A Unique Method for Launching Large Balloons

G.T. Schjeldahl Co.

S.J. Stenlund

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S. J. Stenlund
G. T. Schjeldahl Company
Northfield, Minnesota

Abstract

Balloon launchings are usually complicated by winds which cause giant sails and damage to lightweight balloon material during launch preparation. A unique approach has been suggested to minimize the area of the balloon exposed to the wind prior to launch. The concept uses a short-train tandem system where the main balloon remains packaged until after launch. Then, as the system is ascending and drifting with the wind, the main balloon is unfolded. The payload and balloon container are lowered by lines attached to the base fitting of a launch balloon. When the main balloon is fully extended, the payload weight is transferred from the launch balloon to the main balloon. In the final stage of operation, the container and the load lowering device are jettisoned by parachute for recovery and re-use. As the balloon system continues to ascend, the main balloon inflates in a normal manner.

A simple, lightweight, load lowering device is being developed for this use. It is capable of lowering loads slowly at relatively constant rates despite load changes that occur. This lowering mechanism can be made in several sizes and used in multiple units to cover a wide range of weights and distances to be lowered. A built-in speed sensor on the device can be adjusted to obtain speeds from a few inches to many feet per second. It is capable of lowering variable, as well as fixed weight loads. Because of design simplicity and low cost, it will be of use to most balloon users who need to provide protection for their balloons.

I. INTRODUCTION AND BACKGROUND

Since the first balloons began flying, the scientific balloon community has been considering ways to launch balloons reliably. Numerous methods have been tried with varying degrees of success. The basic problem has been winds during launch preparation. The bigger the balloons have become, the greater the need has been to minimize the effects of winds. Figure 1 shows an example of the giant sail that can be produced when the wind strikes the flaccid portion of a balloon being launched. Various methods and techniques have been used in an attempt to overcome this problem. Some of these are as follows:

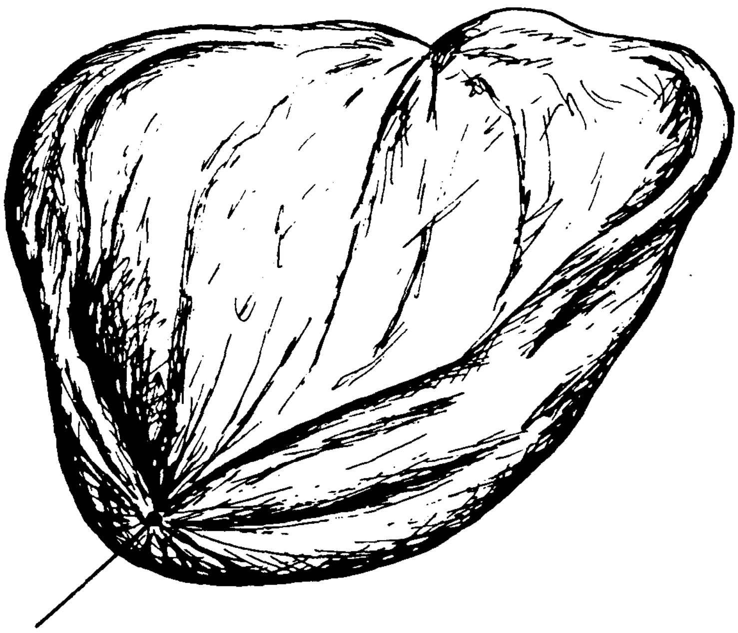

Figure 1. Balloon Sail

1. Inflation of the balloon in a hangar and moving it outside just prior to launch
2. Launch in areas and times of minimum wind
3. Use of a wind screen to protect the balloon
4. Use of a dynamic launch in which the flaccid material is held parallel to the wind prior to launch

5. Placing a removable protective covering around the flaccid portion of the balloon, that is, using a sleeved balloon
6. Launch at sea, moving the launch platform (ship) with the wind

The approaches vary from sheltering the balloon to the brute force method of anchoring the balloon securely to heavy equipment. These methods are usually suitable for special situations, but are limited for general applications because of geography and/or cost considerations.

2. INFLIGHT DEPLOYMENT

The single most important need was a simple, reliable, low-cost balloon launch method that would be available to any scientist for use in any geographical area, at any time of the year. A unique answer to this need was suggested by the National Center for Atmospheric Research (NCAR) in a concept that appears promising. NCAR's approach is to minimize the exposed balloon area to only the volume that is needed to lift the system off the ground. Once it is floating free with the wind, the remaining large area of flaccid balloon material is deployed from the container so that it is ready for inflation as the balloon ascends. This concept has been labeled "The Inflight Deployment Technique". Inflight deployment is a term that needs to be defined. It means deployment of the uninflated portion of the balloon system including, possibly, the instrumentation train and recovery system after the balloon has been launched. A look at some illustrations will help explain how this will work. In Figure 2A we see an inflated balloon on the ground. This balloon is just large enough to contain the gas needed for the mission, which minimizes the area exposed to winds. This portion corresponds to the familiar launch balloon of a tandem system.

The main balloon and payload train are packed in a container ready for deployment immediately beneath the launch balloon. A major advantage is that the main balloon is not exposed until after the launch and after confirmation is received that the launch balloon has survived the lift-off. If there has been damage to either the launch balloon or payload, the balloon system can be valved down and the main balloon recovered intact for later use. This would result in substantial cost savings because the main balloon is usually the much larger and more expensive balloon of the two. If everything is satisfactory, the deployment can proceed.

After the system is floating in a relatively still air, a deployment device is actuated at ground command as shown in Figures 2B and C. Finally, the lowering device and the balloon container fall free from the balloon to parachute back to earth for re-use.

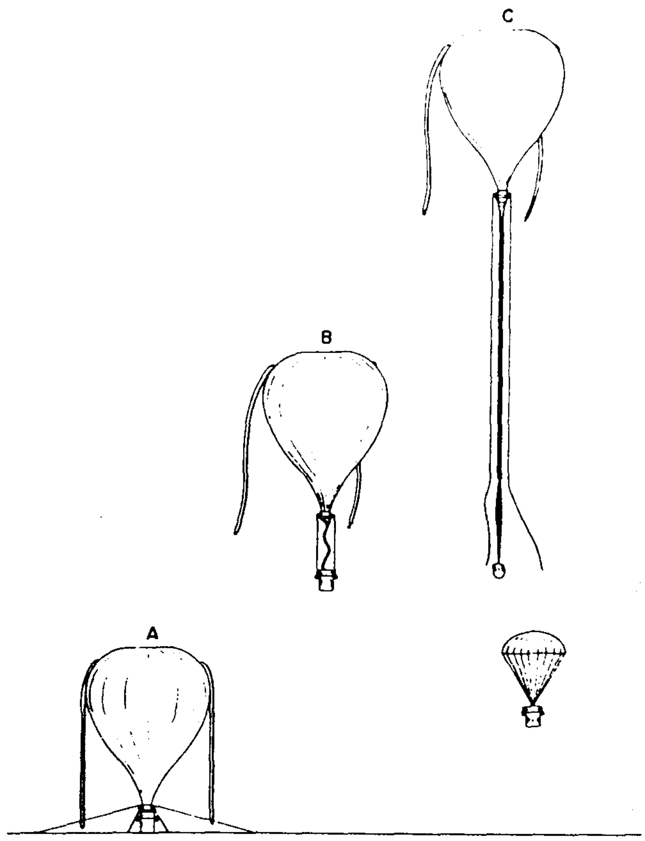

Figure 2. Inflight Deployment for Small Payload

Figure 3 shows how the system would be modified for a large payload that could not be packed in the container. In this instance, the container and lowering device are held in the flight train.

The success of this operation depends on three things:

1. Successful deployment of the main balloon
2. Transfer of the payload from the deployment device to the main balloon
3. A reliable, constant speed, load lowering device

3. OBJECTIVES

The objectives of NCAR's Inflight Deployment study were to develop a balloon launch technique which could be used by many scientists to minimize the effects of winds, reduce the need for costly equipment, provide the capability for launching balloons in more locations, and improve the chances for a successful flight. NCAR

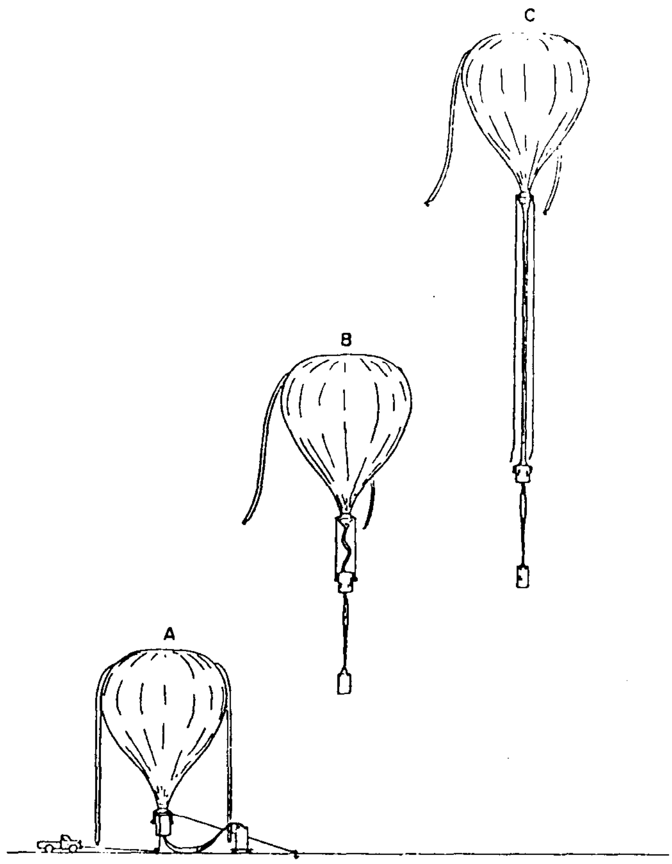

Figure 3. Inflight Deployment for Large Payload

requested a study of this concept and then a definition of the areas that needed to be developed. The objectives of the study were as follows:

1. To review past concepts which were similar in operation
2. To consider new methods or combine known methods which may have application
3. To compare possible approaches and recommend one which appears most promising for further study and testing

After the first portions of the study were complete, guidelines were established to limit the scope of the efforts so that a more concentrated study could continue. Some of the initial guidelines were as follows:

1. A tandem balloon system was selected because it provided the easiest way to confine the initial inflation and to attach the remainder of the system
2. Polyethylene was selected for the main balloon since it was the most fragile material

3. 1000 lb was selected as the maximum payload weight because it covered most of the scientific payloads flown on balloons
4. 500 ft was selected as the distance to be lowered because it represents a length greater than that used for most balloons
5. A load lowering rate of 2 to 5 ft/sec was selected because this was considered the safe unfolding speed for a balloon

After the definition phase, some specific areas investigated were as follows:

1. Balloon packing container
2. Load lowering mechanism
3. Safety for the balloon material
4. Ease of field operation

Of these, the load lowering device proved to be the most challenging.

4. LOAD LOWERING DEVICE

One of the most needed pieces of hardware was a load lowering device to make the inflight deployment concept feasible. Essentially, this had to be an energy absorber that met a number of requirements. Some of these requirements were that the device must:

1. Lower at 2-5 ft/sec without stopping or accelerating
2. Lower 1000 lb 500 ft without overheating (643 BTU of heat energy).
3. Be adjustable to handle various weight loads (Balloon weight decreases as the balloon is deployed)
4. Be lightweight
5. Be simple to use
6. Be low in cost

Numerous energy dissipaters were considered for use in the first part of the study. They ranged from reel and brakes to retro-rockets. After an elimination process, a linear friction brake suggested by NCAR was selected for development.

A linear friction brake consists of a strip of flat webbing between two flat pressure plates as shown in Figure 4. One end of the web is fastened to the top balloon base fitting and the pressure plates or the brake are attached to the balloon container being lowered. The length of webbing to be used in lowering is wound on a spool immediately below the brake. The obvious advantage of this device is its simple construction and few parts.

From tests with a small model, we soon learned that this concept was effective and showed potential in meeting the desired requirements. The materials first used, aluminum and nylon, also turned out to possess some better than expected characteristics. The frictional properties, although not yet fully understood,

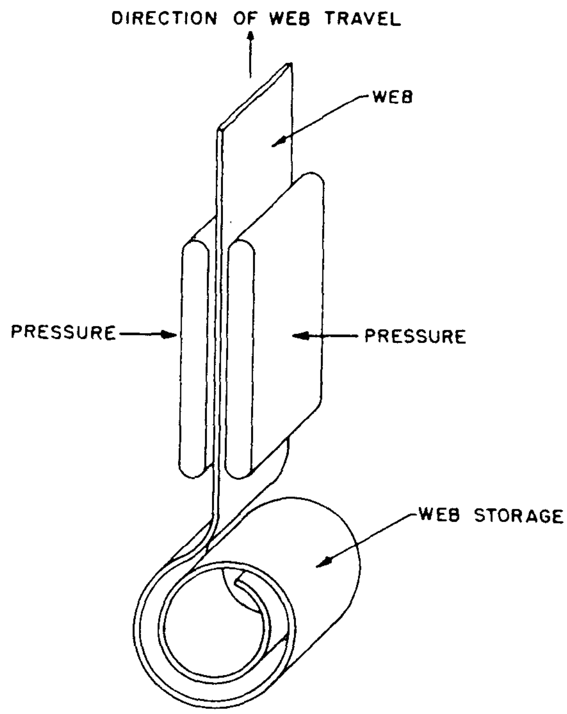

Figure 4. Basic Linear Friction Brake

allowed the device to operate over a wide speed range and resisted stopping. Both materials, of course, were readily available and easy to work with. Further testing showed that the energy absorption ratio had a potential of over 100. Energy absorption ratio was defined as a ratio of the load weight to the brake weight.

Control of the lowering speed was desirable because the load decreases as the balloon is unpacked from its container. This challenge was overcome more easily than had been expected, when two brakes were put in series as shown in Figure 5. The smaller brake is a governor and has a fixed pressure to produce a constant braking force. It is mechanically linked to the larger brake pressure generation system so that it controls the friction generated. Only the governor brake need be adjusted for a given load and speed. It will automatically adjust the main brake when the load is applied. In operation the governor brake exerts a level force on the main brake to maintain a certain speed. If the main brake slides faster, the governor tends to trail further behind and increases the pressure on the main brake to slow it down. If the main brake slows or stops, the governor brake catches up and decreases pressure on the main brake, allowing it to move faster again. This variable load brake has been tested and found to function at relatively constant speeds over a load range of 20 to 120 lb. Figure 6 shows a

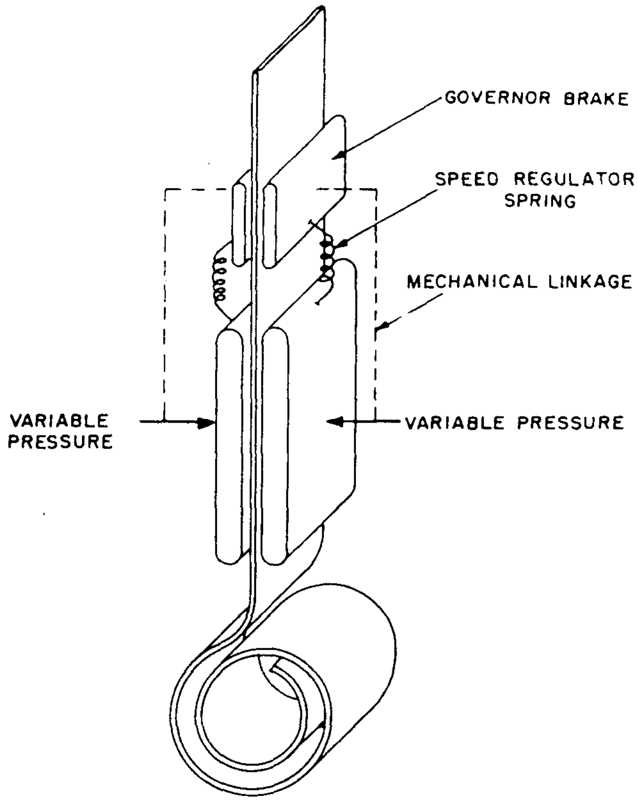

Figure 5. Variable Load Linear Friction Brake

working model. The line, pulleys, and back folding levers supply the mechanical advantage the governor needs to apply to the main brake shoes.

Two problems that remained to be solved were pressure generation and heat dissipation. Several hundred pounds per square inch are required to obtain an energy absorption ratio in the range of 30 to 40. As this factor is increased, pressures increase beyond levels easily obtained with lightweight frames and mechanical levers. Heat generated at high efficiency level builds up rapidly and cannot easily be dissipated from within the pressure generation device.

A single solution to both of these problems appears possible by the addition of force multipliers used in conjunction with the linear friction brake. The multipliers are similar to a snubbing post that is commonly used to hold large forces with a small amount of tension. Figure 7 shows the webbing coming from the load side of the linear friction brake and winding through a series of snubbing posts. Because a multiplier can absorb most of the load placed on a brake system, the friction brake itself can be made small and light, and thus the energy absorption ratio of 100 or more is expected to remain the same or possibly to increase.

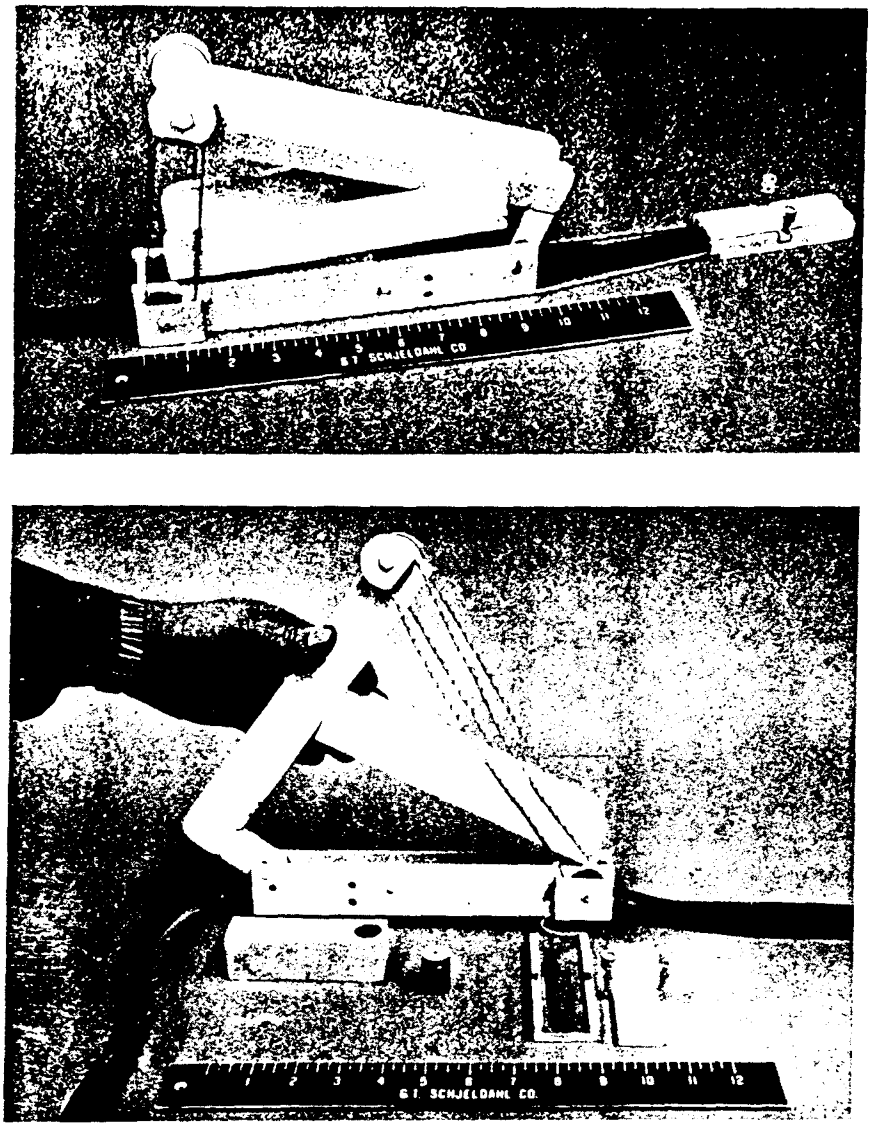

Figure 6. Model of Variable Load, Linear Friction Brake

Also, the snubbers are of simple design, are easy to construct, and have no moving parts. Careful selection of a proper degree of wrap will be required and varying the degree of wrap may perhaps be necessary to obtain the proper balance of loading between the multiplier and the brake. Figure 8 shows a relationship between increased wrap around the cylinder and increased tension. This portion of the study is unfinished, and the results will be reported later.

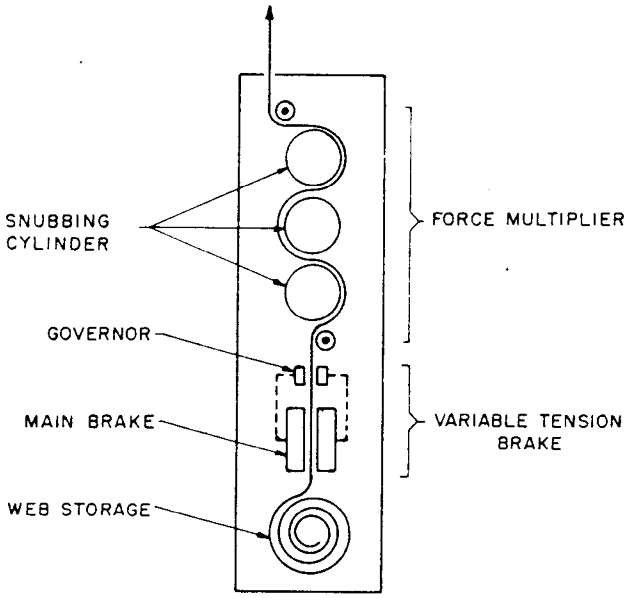

Figure 7. Linear Friction Brake

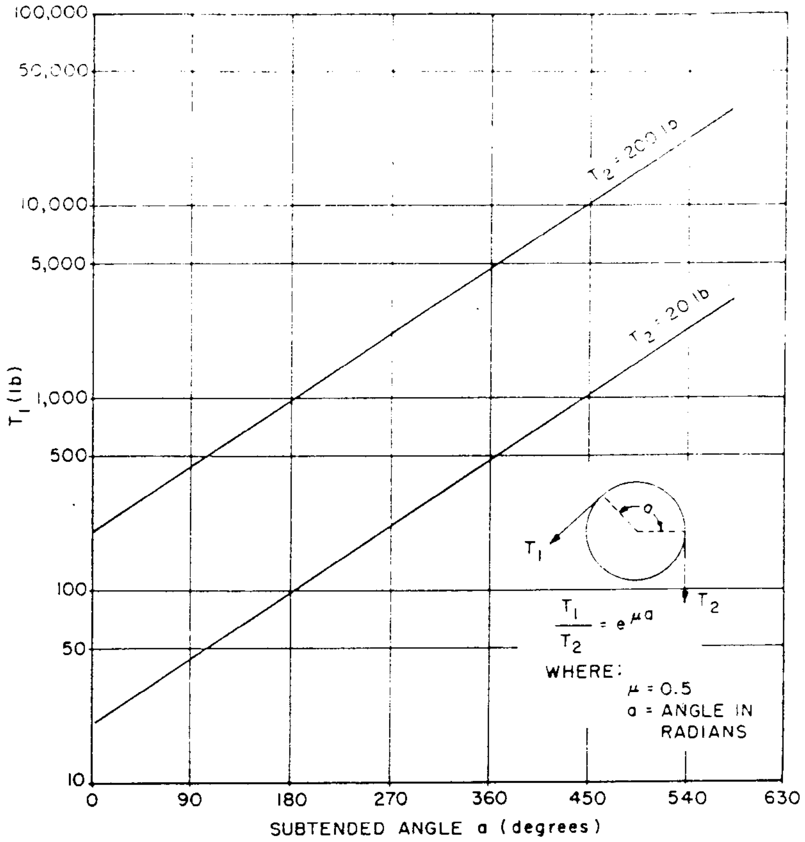

Figure 8. Load Range Vs Degree of Wrap

5. SUMMARY

A new launch technique is being developed which may be employed by many balloon users to reduce costs, simplify launching procedures, increase launch capability and increase reliability despite the hazardous environmental conditions usually encountered during balloon launches.